THE MODIFIED QUADRILATERAL CHARACTERISTIC RELAY

Samir Deghadie [*], Fathy Mabrouk [*] and Kamelia Youssif [**]

[*] Electrical Engineering Department,
Faculty of Engineering, Alexandria University
Alexandria, Egypt

**Alexandria Electricity Distribution Co.,

ABSTRACT

This paper presents a new method for the design of a static impedance relay with characteristic quadrilateral. This relay requires the presence of voltage and current signal but no mixing-the principle of this method depends on the operating criterion, that is $S_v \leq S_I$ where S_v and S_I are restraining and operating input, i.e. without any mixing of signals which proportional to the voltage and current-and it can operate correctly even if the voltage at the relaying point reaches 0.1% of its rated value.

INTRODUCTION

When the number of inputs to a comparator is more than two, then they are termed as multi-input comparators and they could be either amplitude or phase or a combination of the two.

Multi-input comparators give non-classical or discontinuous characteristics e.g quadrilateral characteristics, theoretically the ideal characteristic for distance relays would be a quadrilateral characteristic coincident with the fault area.

If an electromagnetic relay with quadrilateral characteristic is required, such characteristic may be achieved by using four relays with their contacts in series and each having a straight-line characteristic corrosponding to one side of the quadrilateral.

In fact, this characteristic has been achieved in the present work with an induction-cup reactance relay and blinder.

Static relays with quadrilateral characteristic are used nowadays in the protection of short lines. The static relay with quadrilateral characteristic can be obtained through the use of four comparators each having straight line characteristic, tripping occurs if all the outputs of comparator are simultaneously satisfied. In [1] fast three-step solid-state distance relay, with quadrilateral polar characteristic passing through the origin is presented. The relay use multi-input phase comparator. The feature of the comparator design is the minimum interaction between signals designated as restraining signals. Only the operating signal can interact with each of the restraining signals, each interaction resulting in one segment of the quadrilateral. The Pulsating input is made of a ferrite core switching element with an almost rectangular hystresis loop and separate directional unit is used. The disadvantages of this relay are, large number of inputs (8-input) and mixing between input signals (current and voltage). In [2] a new hybrid comparison technique for transmission line protection providing polar characteristics marked by sharp discontinuities is introduced. This technique, combining amplitude and phase comparison, suitably shapes the line current and the voltage to drive the operating and restraining quantities for comparison. The characteristic obtained can either be symmetrical parallelogram, asymmetrical parallelogram, or quadrilateral. The princible of operation of the hybrid comparator is that the output signal S_I drived from maximum value selection (amplitude comparator) of the rectified current quantities, forms the operating quantity of the comparison, and the signal S_v, obtained b^Xxhalf wave rectification of the line voltage, forms the restraining quantity. The signals are fed to an "AND" gate along with voltage V_L. The tripping signal is produced only if $(S_I - S_v)$ does not become negative at any instant during the entire duration of the positive half cycle of V_L. Under close in 3-phase fault condition the value of voltage is near zero and

the input signal proportional to voltage is lost, this condition does not represent a problem when using an amplitude comparator. Using hybrid comparator, the occurence of a close in faults will pose a problem due to the loss of the voltage signal which is required for the operation of the phase comparator, i.e the hybrid comparator requires a memory circuit which memorises the voltage before fault.

In [3] quadrilateral polar characteristic, two static phase-comparison units are used, having their output combined in final "AND" gate. Each static-phase comparator consists of two signal inputs S_1 and S_2, and compared, using "AND" logic, with a waveform of fixed duration, i.e consists of two "AND" gates and time delay. The resultant polar characteristic of the combination is clearly that area in the impedance plane which is common to the characteristics of the two phase comparators considered separately, since tripping pulses must be simultaneously generated by each comparator to initiate circuit breaker tripping. The disadvantage is the output of the two static phase comparators may not occurs at the same time, resulting in wrong tripping.

A new quadrilateral type of distance relay for the protection of short transmission lines by using hybrid comparator was introduced. This quadrilateral relay requires the presence of voltage and current signal and it can operate correctly even if the voltage at the relaying point reaches 0.1% of its rated value.

The way to obtain the quadrilateral characteristic by using Hybrid comparator is a combination of the reactance and blinder characteristics.

HYBRID COMPARATOR [4]

The Hybrid comparator compares amplitude and phase. It is a combination of amplitude comparator and phase comparator. The Hybrid comparators are generally multi-input comparators. The three (or more) inputs are derived from secondary of C.T and P.T by means of replica impedance, mixing transformers and auxiliary C.T. and P.T. This mixing transformer is used to drive the proper proportions of component quantities and to maintain isolation between their inputs and outputs [7]. In Fig. (11) transformers have reactances of X_1 , X_2, K_3 and K_4 are mixing transformers to change the current to voltage with isolation. Two of the input are supplied to an amplitude comparator. The output is compared with third input in a phase comparator. Alternatively, two inputs are phase compared and output is amplitude compared with the third input.

In Figure (1), the phase comparator has two inputs:

$$S_1 = IZ_R(\Theta-\varphi)$$

$$S_2 = V \sin(\omega t)$$

where θ, is the phase angle of Z_R and

ϕ is phase shift between V and I .

To obtain the required output $IZ_R \cos(\Theta-\varphi)$ from this comparator the voltage signal to the comparator must be shifted in phase by 90°, otherwise, the output will be proportional to $\sin(\Theta-\varphi)$ instead of $\cos(\Theta-\varphi)$ as can be seen in figure (2). This shows that the amplitude of the voltage is ineffective and only its phase relation with respect to IZ_R signal is of importance.

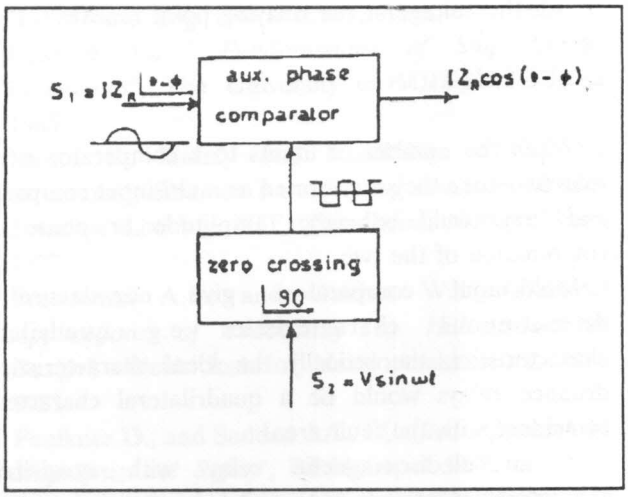

Figure 1. Inputs $IZ_{R,V}$

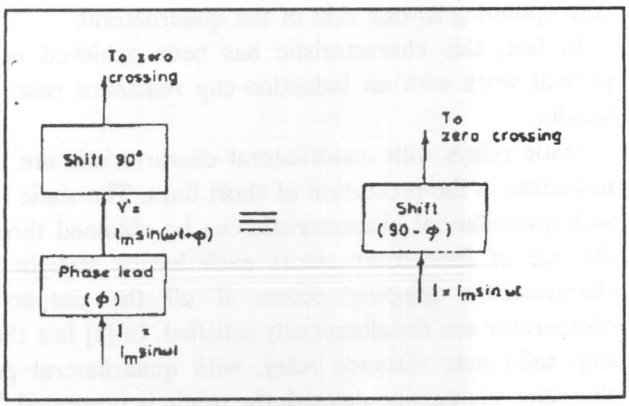

Figure 2. Block diagram of shifter (90 - ϕ).

BLINDER CHARACTERISTICS

The equation of blinder characteristic is

$$Z\cos(\varphi-\Theta) = k$$

or $$V\cos(\varphi-\Theta) = Ik$$

assume $\Theta = -20^\circ$ the equation becomes

$$V\cos(\varphi+20^\circ) = Ik$$

The inputs to amplitude comparator in figure (3-a) are, operating input $S_1 = Ik$ and restraining input $S_v = V\cos(\varphi+20^\circ)$, and tripping condition $S_1 \geq S_v$.

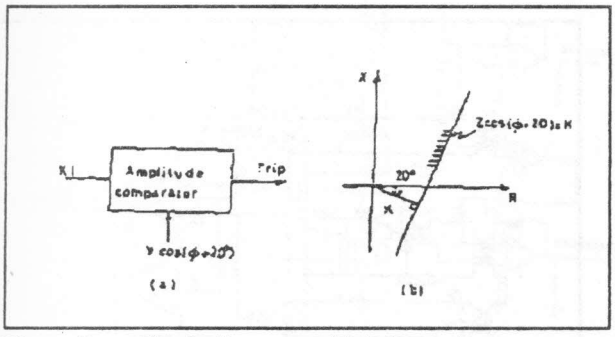

Figure 3. a- Black diagram of binder unit
b- characteristic binder for $\theta = -20^\circ$.

Characteristic of blinder is shown in Figure (3-b), such a relay has been used as a blinder for preventing other protective relays from tripping during very sever power swings [5],[6].

REACTANCE CHARACTERISTIC

The equation of reactance characteristic is

$$Z\cos(\varphi-90^\circ) = k$$

or

$$IZ\cos(\varphi-90^\circ) = Ik$$

under operating input $S_1 = Ik$, restraining input $S_v = IZ\cos(\varphi-90^\circ)$, and tripping condition $S_1 \geq S_v$.

The block diagram and characteristic of the reactance unit are shown in Figures (4-a and 4-b).

The same way to obtain the reactance characteristic and blinder characteristic by using hybrid comparator, can be used to obtain a quadrilateral characteristic having four straight lines (two are reactance lines and two are blinder lines).

The equations to obtain the quadrilateral characteristic shown in Figure (5) are:

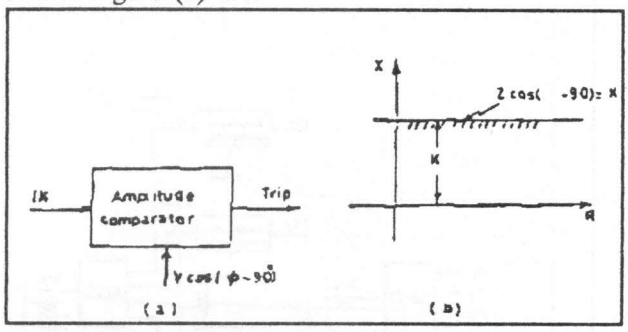

Figure 4. a- Block diagram of reactance uunit
b- characteristic reactance.

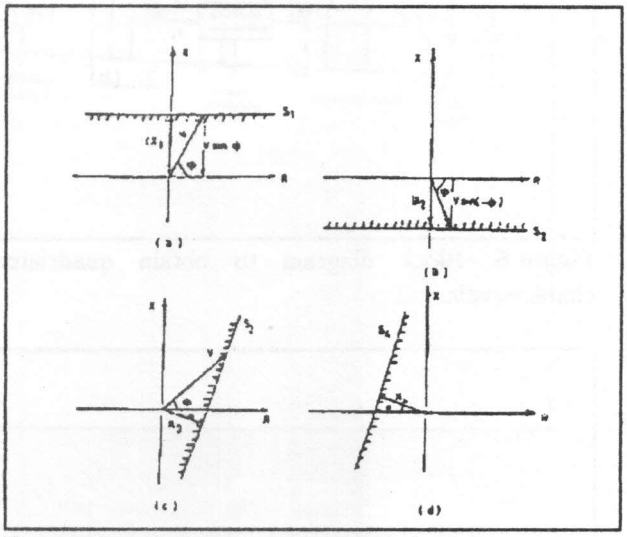

Figure 5. a- Reactance characteristic S_1.
b- Reactance characteristic S_2.
c- Binder characteristic S_3.
d- Binder characteristic S_4.

QUADRILATERAL CHARACTERISTIC USING HYBRID COMPARATOR

$$S_1 = (IX_1 - V\sin\varphi) \geq 0$$

$$S_2 = (IX_2 + V\sin\varphi) \geq 0$$

$$S_3 = (Ik_3 - V\cos(\varphi-\Theta)) \geq 0$$

$$S_4 = (Ik_4 + V\cos(\varphi-\Theta)) \geq 0$$

S_1 and S_2 represent reactance characteristic in positive and negative directions, the circuit arrangement of this reactance characteristic as shown in Figure (6) and Figure (8) .

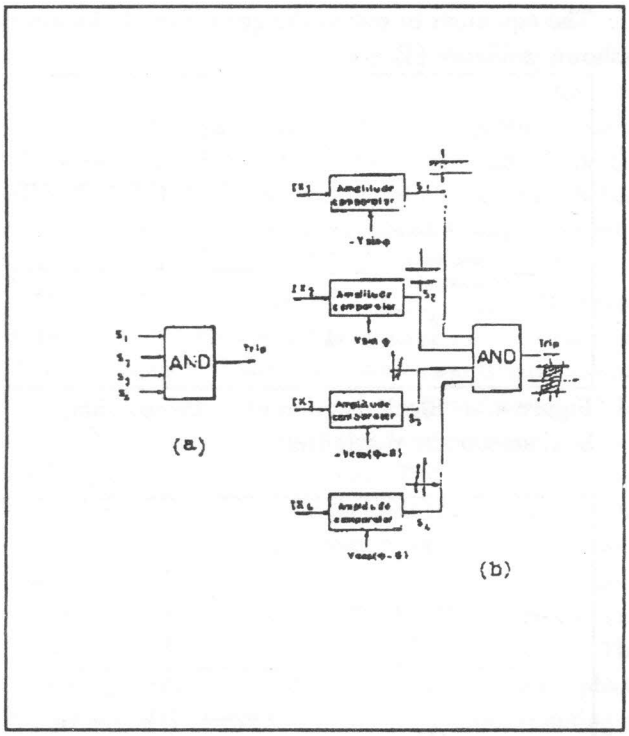

Figure 6. Block diagram to obtain quadriateral characteristic.

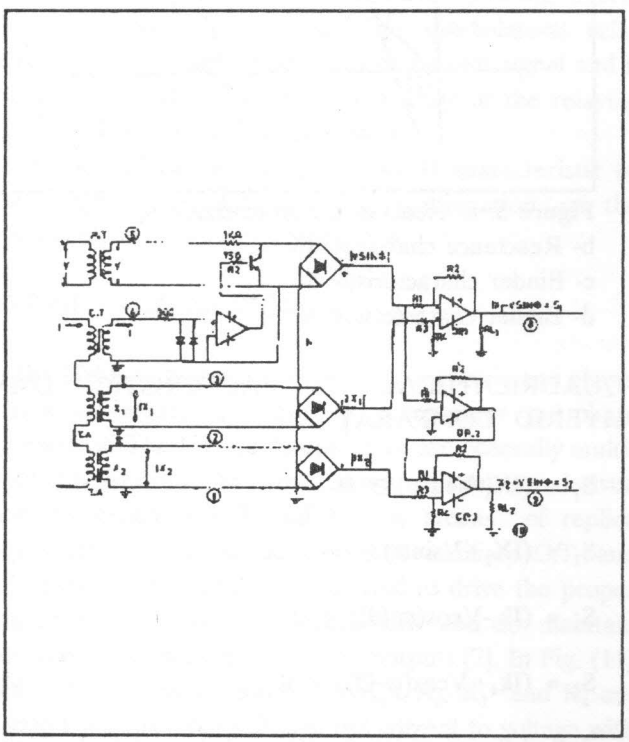

Figure 7. Quadrilateral characteristic.

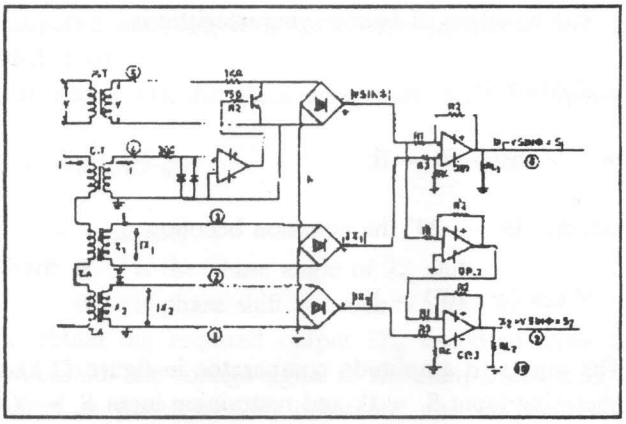

Figure 8. Detailed circuit reactance parts of quadrilateral characteristic.

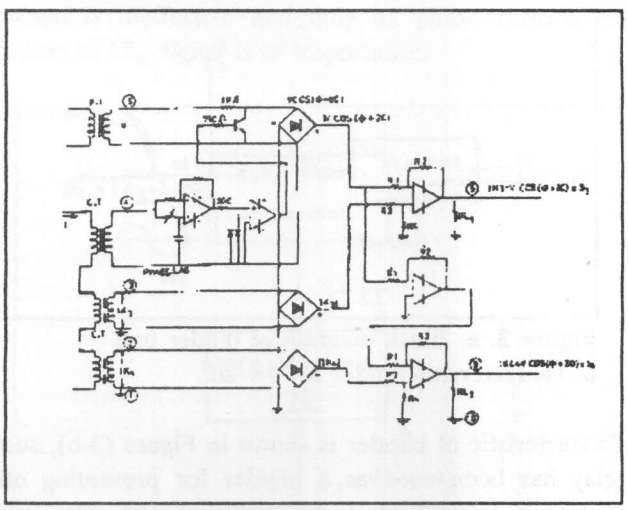

Figure 9. Detailed circuit of blinder parts of quadrilateral characteristic.

S_3 and S_4 represent blinder characteristic in right and left directions as shown in Figure (7) and Figure (9).

The four inputs are fed into an "AND" gate to obtain the quadrilateral characteristic as shown in figure (10), which represents the detailed circuit of quadrilateral characteristic by using hybrid comparator.

PRACTICAL RESULTS

The newly proposed hybrid relay shown in figure (10) and the detailed circuits in Fig. (8.10) are designated by authors and built in Electrical Engineering Department Laboratory, Faculty of Engineering, Alexandria University, Egypt, by choosing their individual components according to their function in the relay. The tests are carried out using the test equipment available in Alexandria Electricity

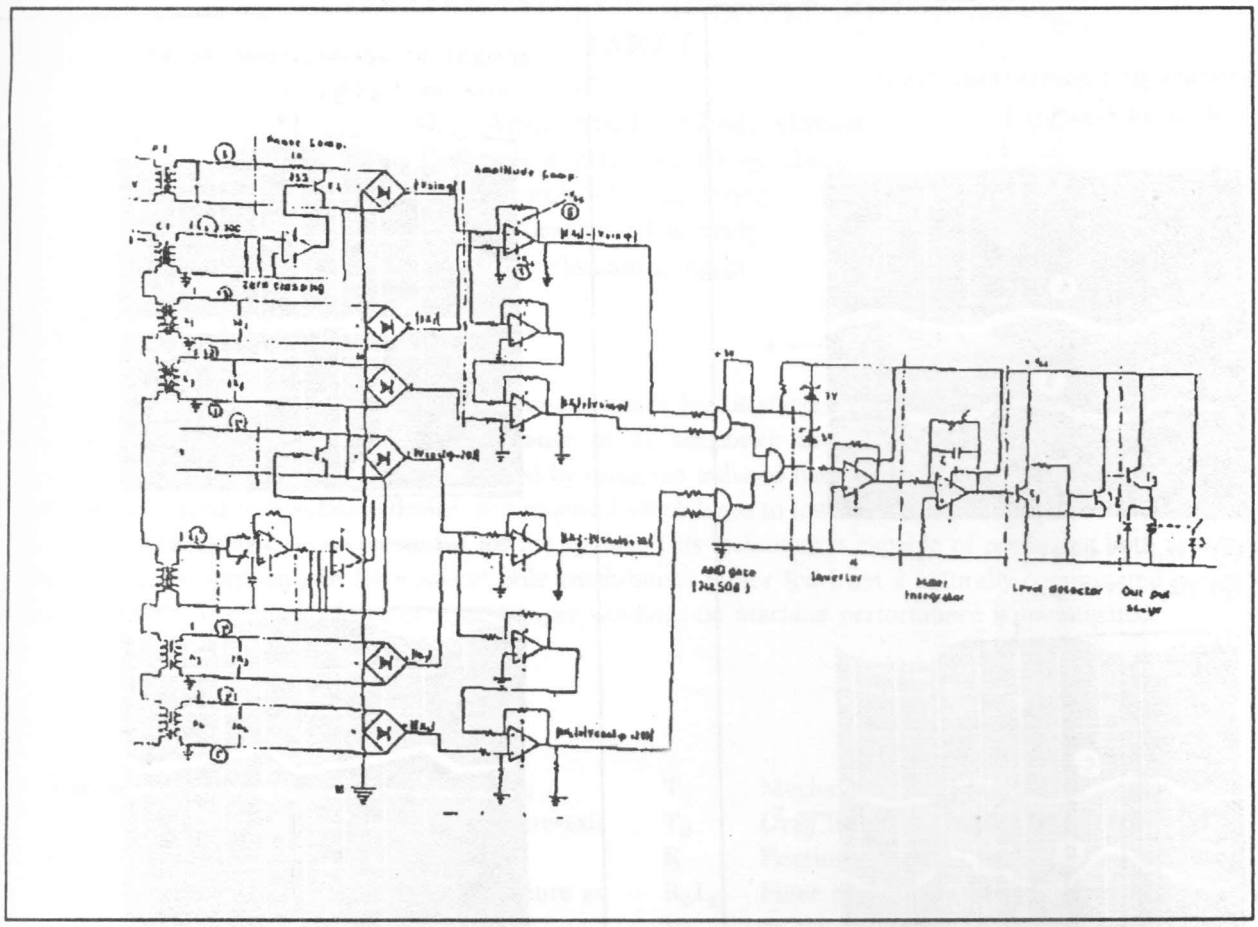

Figure 10. Detailed circuit of quadrilateral characteristic.

Distribution Company. In figure (10) the values of S_1, S_2, S_3 and S_4 are related to the actual voltage and current of the transmission line to be protected. By mean of oscilloscope in Electrical Engineering Department laboratory, Alexandria University the input waves S_1, S_2, S_3 and S_4 are demonstrated in figure (11), the wave-forms at the input and output of the integrator are shown in figure (12). The output wave gives the signal which operates the tripping relay.

CONCLUSION

When the number of the inputs to a comparator is more than two, then they are termed as multi-input comparator and they could be either amplitude or phase or a combination of them.

Multi-input comparator gives non-classical characteristics as quadrilateral characteristic. Theoretically the ideal characteristic for distance relays would be a quadrilateral coincident with the fault area, and tripping occurs if all outputs of the comparator are simultaneously satisfied.

The relay system operates according to the trip condition which is represented by the output signal voltage of miller integrator as shown in figure (12).

The newly proposed Hybrid type relay having a quadrilateral characteristic is suitable for protection of short transmission lines by using hybrid comparator. This relay has advantages, that the number of input signals used is less compared with those of the commercially available relay. Moreover, no mixing of signals is used.

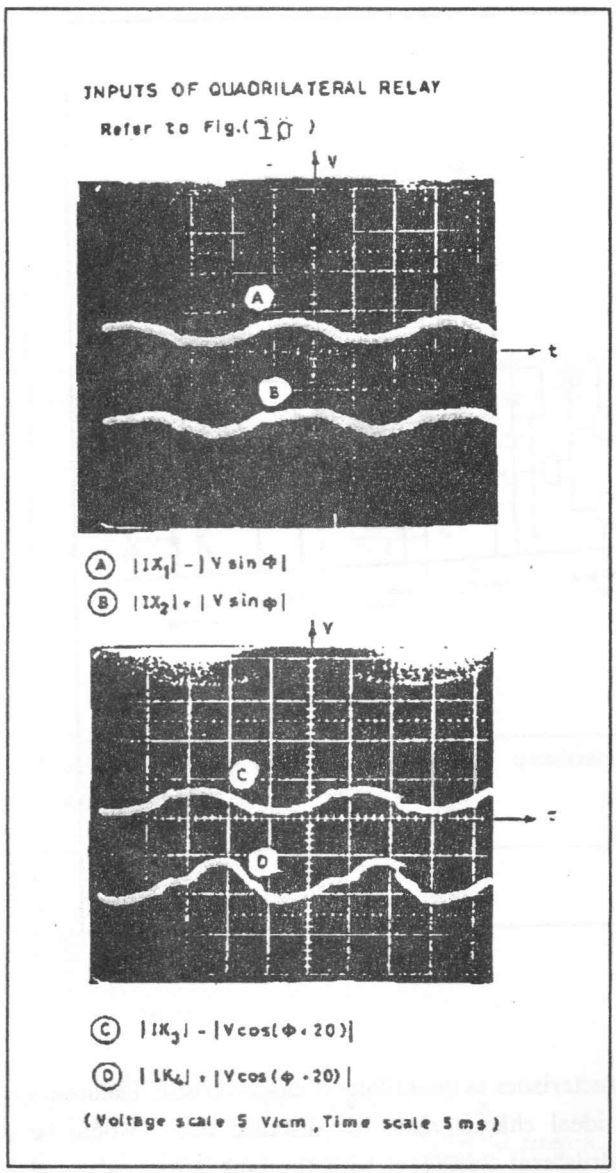

Figure 11.

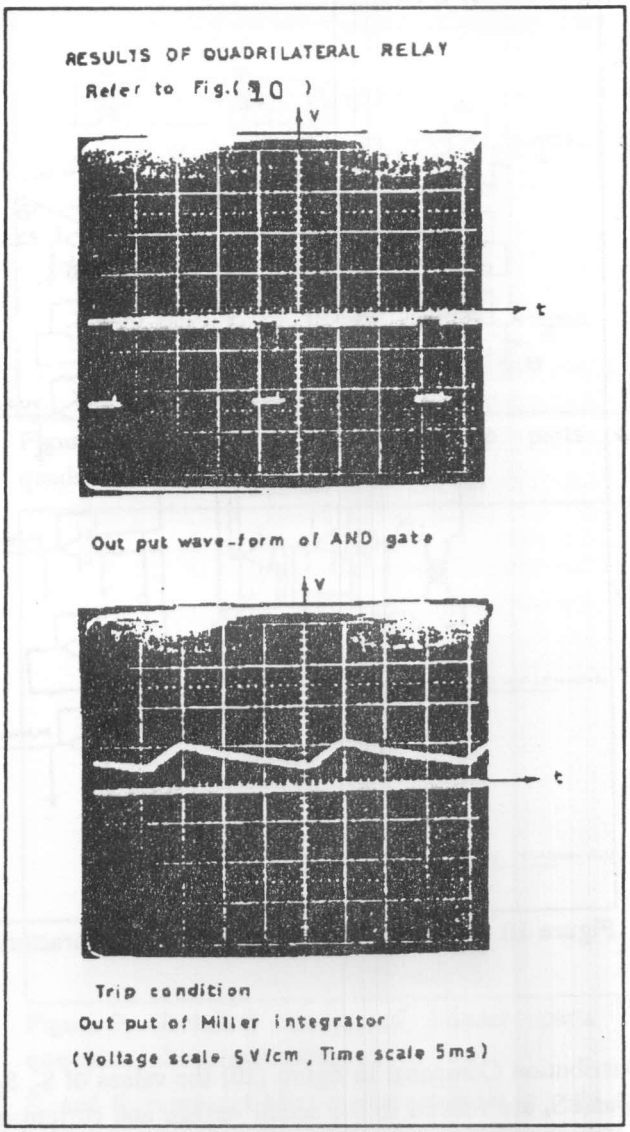

Figure 12

REFERENCES

[1] Fast Three-Step Solid State Distance Relays. Electrical Timers, 9 January 1969.

[2] Hybrid Comparison Technique for Distance Relays, IEEE transactions on Power Apparatus and Systems March/April, 1971.

[3] Developments in phase comparison techniques for distance protection, Proc. IEE, Vol. 112, No. 7, July, 1965.

[4] A New Approach to Electronic Impedance Relays. Alex. Eng., J., Alex. Univ., Volume 28 No.4, pp 521-542. 1989.

[5] Protective Relays: Their theory and practic. Volume two, By A.R. Van, C. Warrington.

[6] BBC Technical Fundamentals H.V. distance relays, Selection and Setting.

[7] Power System Protection, by S.P. Parta, Oxfored and IBN Publishing Co. New Delhi.